Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Central and Arctic, and Quebec regions
Canadian Science Advisory Secretariat
Science Advisory Report 2013/041

RECOVERY POTENTIAL ASSESSMENT OF HICKORYNUT (*Obovaria olivaria*) IN CANADA

*Hickorynut (*Obovaria olivaria*). Photograph by Environment Canada, reproduced with permission.*

Figure 1. Distribution of Hickorynut in Canada

Context:

*In May 2011, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Hickorynut (*Obovaria olivaria*) and determined the designation to be Endangered. The reason provided for this designation was that, "This freshwater mussel lives in mid-sized to large rivers in southern Ontario and Quebec. There has been an historical decline in the species' distribution with losses of the populations in the Detroit and Niagara rivers. Other locations are threatened by the continuing invasion of dreissenid mussels. In addition, the one known host of this mussel, the Lake Sturgeon, is at risk and may be declining in some locations where the mussel is known to still occur. The species is also affected by degraded water quality in many freshwater systems in southern Ontario and Quebec". Hickorynut is currently not listed under the* Species at Risk Act *(SARA).*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of DFO regarding the listing of the species under the SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of Hickorynut in Canada.

September 2013

Canada

SUMMARY

- In Canada, the current and historic known distribution of Hickorynut is limited to four confirmed populations, one of which is currently considered to be extirpated. Extant populations include the Mississagi River (Lake Huron drainage), the Ottawa River and its tributaries (Coulonge River), and the St. Lawrence River and its tributaries (Assomption River, Saint-Francois River and Batiscan River; Figure 1).
- Hickorynut glochidia must encyst on the gills of an appropriate host fish to survive and metamorphose. The putative host fish for Hickorynut in Canada is Lake Sturgeon (*Acipenser fulvescens*). This is supported by laboratory infestation experiments and a direct overlap in the distribution of the two species.
- Adult Hickorynut habitat is generally described as sand or mixed sand gravel substrate in relatively deep water with moderate to fast water velocity in large river systems.
- It appears that the greatest limiting factors to the stabilization and growth of Hickorynut populations in Canada are largely attributed to the introduction and establishment of dreissenid mussels and decreases in the quality of available habitat. In addition, due to the obligate glochidial encystement stage, Hickorynut is also directly affected by host fish abundance and indirectly by the threats affecting the host fish.
- If the host species abundance is not limiting, Hickorynut population growth is most sensitive to perturbations that affect adult and juvenile survival, moderately sensitive to the age at maturity, and relatively insensitive to proportional changes in glochidial survival, fecundity, or maximum age. If host abundance is limiting, Hickorynut viability becomes sensitive to the rate of glochidial attachment.
- Given a stable host abundance and a growing mussel population, the expected mussel abundance can be calculated using the mussel life history parameters.
- Mussel population abundance was very sensitive to the availability of juvenile hosts, and much less sensitive to the availability of adult hosts.
- A number of key sources of uncertainty exist for this species related to population distribution, structure, habitat preferences and to the factors limiting their existence. Specifically, there is a need for a continuation of quantitative sampling to confirm the current population status assessment, and to determine population sizes. As Hickorynut is often found in deeper water, additional experimental sampling methods should be investigated to sample these deep-water habitats. Supplementary laboratory experiments, and if feasible, field experiments should be completed to determine if Lake Sturgeon is indeed the host fish for Hickorynut in Canada.

BACKGROUND

In May 2011, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Hickorynut (*Obovaria olivaria*) and determined the designation to be Endangered. The reason provided for this designation is that, "This freshwater mussel lives in mid-sized to large rivers in southern Ontario and Quebec. There has been an historical decline in the species' distribution with losses of the populations in the Detroit and Niagara rivers. Other locations are threatened by the continuing invasion of dreissenid mussels. In addition, the one known host of this mussel, the Lake Sturgeon, is at risk and may be declining in some locations where the mussel is known to still occur. The species is also affected by degraded water quality

in many freshwater systems in southern Ontario and Quebec". Hickorynut is currently not listed under the *Species at Risk Act* (SARA).

When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on the Hickorynut populations in Canada and is a summary of the conclusions and advice from a Canadian Science Advisory Secretariat peer-review meeting that occurred on January 29-30, 2013 in Burlington, Ontario. Two research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (Bouvier et al. 2013), and a second on allowable harm, population-based recovery targets, and habitat targets (Young and Koops 2013) provide an in-depth account of the information summarized below. Proceedings that document the activities and key discussions of the meeting are also available (DFO 2013). Please note that reference citations have been removed from the following document to minimize the length of the document. Complete reference citations are available at Bouvier et al. (2013) and Young and Koops (2013).

Species Description

Hickorynut is a medium-sized freshwater mussel with an average shell length of approximately 55 mm. A maximum shell length of 100 mm has been reported; however, most individuals are generally less than 75 mm long. The shell is described as being almost perfectly oval and inflated with rounded anterior and ventral margins. Although sexual dimorphism is subtle, the posterior margin of males is described as being bluntly rounded, while that of the female is described as being broadly rounded. The shell is generally thicker anteriorly and thinner posteriorly. The beak is inflated, directed forward and very close to the anterior end of the shell. The exterior of the shell (periostracum) varies from olive-green to yellowish-brown with faint greenish rays in juveniles, while older specimens tend have a dark brown periostracum. The nacre is bright white and often iridescent posteriorly.

Similar Species

Globally, there are only four additional species in the genus *Obovaria* (*O. jacksoniana, O. retusa, O. subrotunda, and O. unicolor*). Of these additional four species, only the range of Round Hickorynut (*O. subrotunda*) extends into Canadian waters. Hickorynut is easily distinguished from all other freshwater mussels in Canada by its relatively small, nearly oval shell shape, its unique hinge-plate features and the peak of its shell located far anteriorly. Morphologically similar species include Round Hickorynut, Round Pigtoe (*Pleurobema sintoxia*), and Mucket (*Actiononaias ligamentina*). Round Hickorynut can be distinguished from Hickorynut by its rounded shell and vertically aligned pseudocardinal teeth. Hickorynut pseudocardinal teeth are aligned horizontally. The shell of Round Pigtoe generally has a darker color and is more compressed with smaller beaks. Mucket can be distinguished from Hickorynut by the presence of green rays and heavy, well-developed teeth.

Age and Growth

Investigation into the age of Hickorynut in Canada by examination of the distinct dark bands on the external surface of the shells of individuals from the Ottawa River indicated that most Hickorynut adults ranged in age from seven to 14 years.

Diet

Like most other unionid mussels, Hickorynut is considered to be a filter feeder. Food items may include phytoplankton, organic detritus, and bacteria. In the early juvenile stage, when the mussel is most commonly buried in the substrate, food is obtained directly from the substrate. Species-specific dietary information is not available for Hickorynut.

ASSESSMENT

Current Species Status

In Canada, the current and historic known distribution of Hickorynut is limited to four confirmed populations, one of which is currently considered to be extirpated. Extant populations include the Mississagi River (Lake Huron drainage), the Ottawa River and its tributaries (Coulonge River), and the St. Lawrence River and its tributaries (Assomption River, Saint-Francois River and Batiscan River; Figure 1). The largest population of Hickorynut in Canada is located in the St. Lawrence River near the city of Grondines, Quebec where repeated sampling between 2007 and 2012 has yielded the capture of over 550 live individuals. It should be noted that the following maps represent all current and historic records of Hickorynut, and may not accurately represent the current distribution. Deep water, the habitat most often associated with Hickorynut, has not been extensively sampled and therefore the following maps may be an underrepresentation of the current distribution.

Mississagi River

The Mississagi River originates in the Sudbury district in Ontario and flows approximately 226 km south to Lake Huron. The first Hickorynut record from this river was recorded near Blind River, Ontario in 1955 (Figure 2). Two additional weathered shells have been confirmed from the Mississagi River, although the date associated with these shells was simply listed as prior to 1960. Hickorynut was not recorded from this system again until 2000 when one fresh shell was incidentally collected while conducting botanical fieldwork. This area was not revisited until September 2009 when SCUBA and snorkeling surveys were completed at five sites, two of which resulted in positive identifications for a total of ten Hickorynut.

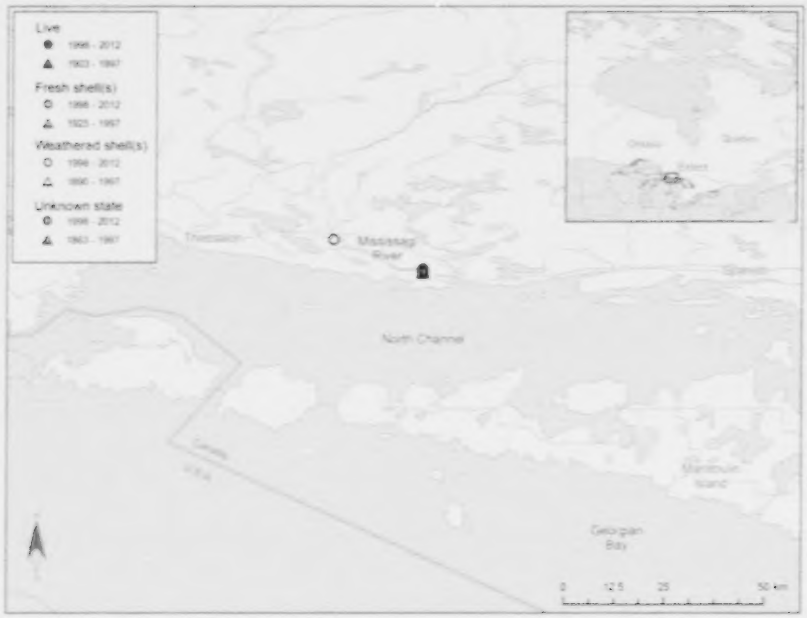

Figure 2. Distribution of all known current and historic Hickorynut records from the Mississagi River, Ontario.

Ottawa River

Historical museum records of Hickorynut from the Ottawa River are available from 1885, 1887, 1900, 1906, 1931, 1933, 1936, 1937, 1960, and 1962. This species was not observed from this system again until 2000 when one fresh shell and two weathered shells were recorded during an observational study. Subsequent to this observational study, additional extensive targeted sampling by CMN, the Ministère des Ressources naturelle et de la Faune du Québec (MRNF), and the Bishop Mills Natural History Museum have occurred in 2001, 2002, 2004-2005, 2007, 2010 and 2012 throughout the Ottawa River. These studies resulted in the observation of live Hickorynut (n=6), fresh shells (n=52) and weathered shells (n=23) in the Ottawa River from the Chenal-de-la-Culbute in the vicinity of the Ile-aux-Allumettes, Quebec to Parc de Plaisance, Quebec (Figure 3). Hickorynut have also been found in a few tributaries of the Ottawa River. There is a single record of a weathered shell from the Madawaska River; although there was no date associated with this collection. In addition, one live individual was found in 2001 in the Coulonge River approximately 6 km from the confluence with the Ottawa River.

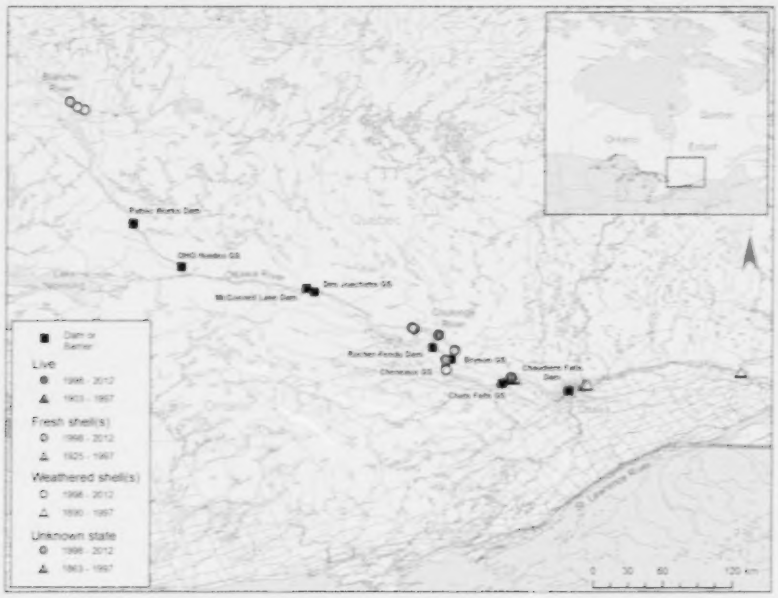

Figure 3. Distribution of all known current and historic Hickorynut records from the Ottawa River.

St. Lawrence River and Tributaries

Evidence of the presence of Hickorynut populations is noted through the St. Lawrence River from the southern point of the Charron Island (near Montreal, Quebec) downstream to the town of Saint-Joseph-de-la-Rive, Quebec, as well as in three of its large river tributaries: the Saint-François River, the Batiscan River and the Assomption River (Figure 4).

St. Lawrence River

The first historical record of Hickorynut from the St. Lawrence River is from an 1863 account of the freshwater mussels of lower Canada. Subsequent to this initial account, there are historical records of Hickorynut from the St. Lawrence River from 1890, 1905, 1947, 1953, 1974 and 1982.

More recently, the MRNF have undertaken substantial sampling efforts to record the presence and estimate the abundance of Hickorynut throughout the St. Lawrence River. Most notable, was the discovery of what is considered to be the largest population of Hickorynut in Canada near the municipality of Deschambault-Grondines, Quebec. Sampling efforts at this site since 2007 have resulted in the capture of 586 live individuals, 17 fresh shells and 33 weathered shells (information on whether these live individuals were recaptures was not available). Surveys in 2007 resulted in an estimated abundance of 0.75 individuals/m^2. Surveys at Grondines from 2007 to 2012 recorded the presence of numerous juvenile Hickorynut providing evidence that recruitment is occurring at this site. In addition, 72 fresh shells were recorded in 2010 at Berthierville.

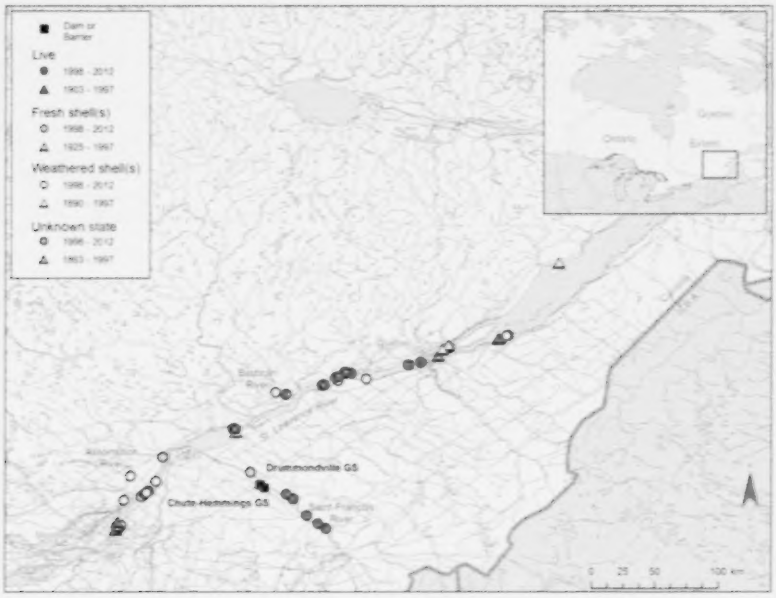

Figure 4. Distribution of all known current and historic Hickorynut records from the St. Lawrence River and its tributaries.

Extensive sampling for Hickorynut occurred throughout the St. Lawrence River in 2012 by the MRNF. It should be noted that live individuals were only observed from downstream sites, while only weathered shells were observed at upstream sites. Shell lengths from all live Hickorynut and fresh shells observed from 2005 to 2012 were recorded.

Saint-François River

The Hickorynut population from the Saint-François River was first discovered in 2002, when one fresh shell and 23 weathered shells were recorded. Since the initial discovery of this population, 15 live individuals and seven weathered shells have been recorded from this system. Of these records, one fresh shell and 13 weathered shells were recorded at a single site downstream of Drummondville, Quebec at Saint-Joachim-de-Courval, Quebec, while the remaining individuals were recorded from seven sites upstream of Drummondville. The upstream site is approximately 2 km north of the hydroelectric dam at Windsor.

Batiscan River

The Batiscan River is a large river system that flows into the St. Lawrence River at a point downstream and northeast of Trois-Rivières, Quebec. Hickorynut was first discovered in the Batiscan River in 2002 when 14 live individuals, two fresh shells, and one weathered shell was recorded from a site approximately five kilometers downstream from its confluence with the St. Lawrence River. Subsequent to its discovery, Hickorynut have been recorded from this site on the Batiscan River in 2003 (one fresh shell), 2005 (six live individuals, one weathered shell), and 2006 (five live individuals). Hickorynut is only known from one additional site in the Batiscan River, approximately 8 km upstream from the site of discovery. A single weathered shell was collected from this upstream site in 2006. Shell length was noted for 11 live individuals and two weathered shells recorded during the 2005-2006 surveys.

Assomption River

There are only two records of Hickorynut from the Assomption River. The first consists of two weathered shells collected in 1998 and the second consists of a single weathered shell collected in 2001. Limited information is available regarding Hickorynut at present in this system. Additional sampling is needed to determine whether an extant population of Hickorynut is present.

Great Lakes and Connecting Channels (extirpated)

Prior to the introduction of the invading dreissenid mussels Hickorynut occurred at very low numbers throughout the Great Lakes and their connecting channels. The likely extirpation of Hickorynut from the Great Lakes and their connecting channels has been attributed to the introduction of dreissenid mussels.

There is only a single record of Hickorynut from the Great Lakes proper, located in Lake Erie (1925) (Figure 5). The only record is from the north shore of Lake Erie near Oxley, Ontario. Very limited locational information is available for this record, and the state of the specimen (fresh or weathered shell) was not recorded.

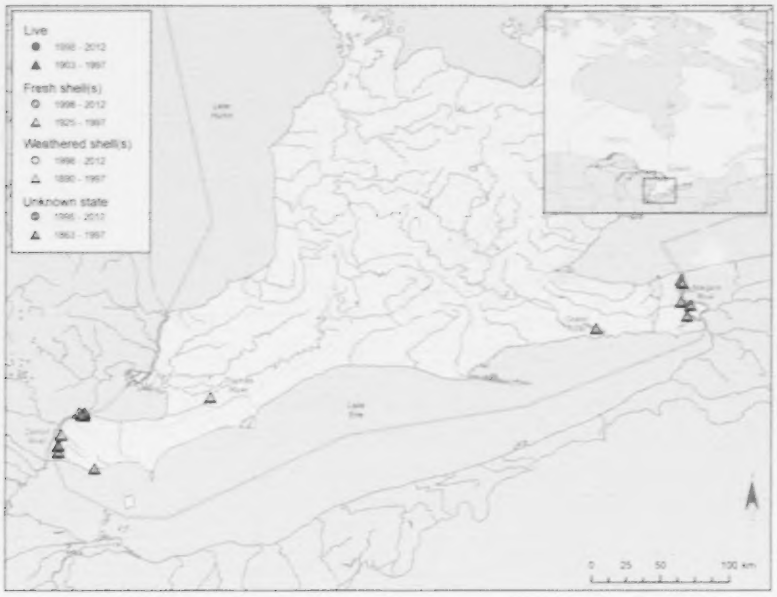

Figure 5. Distribution of all known current and historic Hickorynut records from Great Lakes and their connecting channels.

Hickorynut was first noted from the Detroit River in 1934. This species was subsequently reported from this system in 1982 (nine live individuals), 1992 (one live individual, five fresh shells), and 1994 (one fresh shell). The 1994 record was to be the last Hickorynut record from the Detroit River. Additional sampling occurred in the Detroit River in 1996 but did not yield any Hickorynut.

Records from 1903, 1931, 1932, 1934 and 1935 provide supporting evidence of an historical Hickorynut population in the Niagara River. The New York Power Authority commissioned a study to the Riveredge Associates LLC aimed at surveying the mussel assemblage on the American side of the Niagara River in 2001 and 2002. Although Hickorynut was not found alive,

numerous weathered and sub-fossil shells were inventoried, indicating a once-productive population. Additional sampling of preferred habitat is necessary in Canadian waters to verify that Hickorynut is currently extirpated from the Niagara River.

There is a single record of Hickorynut in the Grand River, Ontario from 1963. The record did not indicate the state of the shell, but only specifies that the individual was found directly below the dam at Dunnville, Ontario.

A single record of Hickorynut exists for the Thames River, Ontario from 1934. This record consists of a single fresh shell and was verified to be Hickorynut by the authors. Extensive unionid sampling has occurred in this system over the past two decades, and it is believed that Hickorynut no longer exists in this system.

Population Status Assessment

For the purposes of this RPA, populations have been delineated based on the ability of the host fish to move from one location where Hickorynut is known to exist to another. The putative host for Hickorynut is Lake Sturgeon. Lake Sturgeon distribution in Canada directly overlaps that of Hickorynut. A thorough review of Lake Sturgeon abundance and distribution in various reaches of the Ottawa River is available. The ability of Hickorynut to disperse via its host fish during the obligate parasitic phase was considered when determining the population structure used for the Population Status Assessment.

To assess the population status of Hickorynut in Canada, each population was ranked in terms of its abundance and trajectory. The level of certainty was associated with each assignment (1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion). The Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Extirpated (Table 1). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to Bouvier et al. (2013) for details on the methods used in the assessment of Population Status.

Table 1. Population Status of all Hickorynut populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
Mississagi River	Poor	3
Ottawa River	Poor	3
St. Lawrence River	Poor	3
Saint-François River	Poor	3
Great Lakes and connecting channels	Extirpated	3

Habitat Requirements

Glochidium

To fully understand the habitat requirements of freshwater mussels, we must first understand their unique life cycle (see Bouvier et al. 2013 for a detailed account of the lifecycle of Hickorynut). Hickorynut is classified as a long-term brooder, spawning in late summer, brooding their glochidia over the winter and subsequently releasing their glochidia the following summer. Gravid females with glochidia have been found from August to June of the following summer. Gravid females have been observed during September surveys of the Mississagi River, as well

during October surveys in the Ottawa River. Regardless of brooding strategy, once females release their glochidia they must encyst on the gills of an appropriate host fish.

Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) is the only host fish recorded to have been successfully infested by Hickorynut glochidia in a non-laboratory setting. A subsequent laboratory experiment provided evidence that Lake Sturgeon may also act as a host fish for this species. This relationship was further explored in additional Hickorynut infestation experiments where Shovelnose Sturgeon, Pallid Sturgeon (*S. albus*) and Lake Sturgeon were all found to be suitable hosts, transforming a significant number of juveniles in a laboratory setting

Additional successful infestation experiments, with Lake Sturgeon as the host, have been conducted at the Genoa National Fish Hatchery, Genoa, Wisconsin. Typically, 15-20 cm Lake Sturgeon are used in the infestation experiments and as many as 1200 juvenile Hickorynut have been recovered from a single fish. When held at approximately 21°C, juveniles release 20 to 25 days post-infestation.

Shovelnose and Pallid sturgeons do not occur in Canadian waters, while the distribution of all remaining Canadian Hickorynut populations directly overlaps with those of Lake Sturgeon. This overlap in distribution provides circumstantial evidence to the probable host-mussel relationship between Hickorynut and Lake Sturgeon. Many factors must be considered when discussing the suitability and probability of a successful host fish encounter. The host fish must not only be present in the system in sufficient numbers, but must be of appropriate age, health and immunity to be susceptible to infestation and act as a candidate host fish. Specific criteria related to these factors are currently unknown for the Hickorynut and Lake Sturgeon interaction and should be the focus of future studies.

Glochidia will remain encysted on the host fish until they metamorphose into juveniles. Encystement is an obligate step in the life cycle of Hickorynut and development will not occur in the absence of this phase. The gills of the appropriate host fish can be considered a habitat requirement for the glochidial life stage of Hickorynut.

Juvenile

Subsequent to metamorphosis, juvenile freshwater mussels are released from the gills of the host fish and bury themselves in the substrate until maturity. Time to maturity can vary from one mussel species to another and accurate estimates are not known for most species. It is difficult to classify required habitat for juvenile mussels because they are difficult to detect and because they have a tendency to burrow. Once sexually mature they emerge from the substrate to participate in gamete exchange.

Adult

Adult Hickorynut habitat is generally described as sand or mixed sand gravel substrate in relatively deep water with moderate to fast water velocity in large river systems. Additional details of adult habitat preferences are discussed in Table 2.

Residence

Residence is defined in SARA as "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating". Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during glochidial, juvenile and adult life stages, Hickorynut does not construct a residence during its life cycle (DFO 2010).

Functions, Features and Attributes

A description of the functions, features, and attributes associated with Hickorynut habitat can be found in Table 2. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Hickorynut. In addition to the habitat function, a feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. Optimal habitat attributes from the literature for each life stage have been combined with habitat attributes from current records (records from 2002 to present) to show the maximum range in habitat attributes within which Hickorynut may be found (see Table 2, and references therein). This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from those presented in the scientific literature as Hickorynut may be currently occupying areas of sub-optimal habitat where optimal habitat is no longer available.

Table 2. Summary of the essential functions, features and attributes for each life stage of Hickorynut. Habitat attributes from published literature, and habitat attributes recorded during recent Hickorynut surveys (captured over the last 10 years or since 2002) have been combined to derive the habitat attributes required for the delineation of critical habitat (see text for a detailed description of categories).

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawning and fertilization (long-term brooder: gravid females with glochidia found between August to June; COSEWIC 2011)	Reproduction	Large river systems		• Gravid females observed at the same locations as other non-spawning adult Hickorynut in the Mississagi and Ottawa rivers (COSEWIC 2011)	• Same habitat as adults
Encysted glochidial stage on host fish until drop off	Development	Appropriate host fish	• Natural infestation of Hickorynut on gills of Shovelnose Sturgeon (Howard 1914 and Coker et al. 2001 in Watters et al. 2009) • There are no historic records of natural infestation of Lake Sturgeon by Hickorynut • Hickorynut successfully transformed in Lake Sturgeon infestation experiments (Brady et al. 2004; B. Sietman, unpubl. data; M. Hove, unpubl. data; N. Eckert, unpubl. data) • Lake Sturgeon distribution directly overlaps Hickorynut distribution (Pratt 2008) providing circumstantial evidence of host fish interaction	• There are no records of natural infestations of Hickorynut glochidia on gills of Lake Sturgeon	• Presence of sufficient host fish (putative host fish in Canadian waters is Lake Sturgeon)
Adult/juvenile	Feeding Cover Nursery	Large river systems with flow within the range of natural variability	**Stream characteristics** • Categorized as occupying large, deep, wide river systems, relative to other Canadian freshwater mussel species (COSEWIC 2011) • Recorded at depths ranging from 0.5 to 9.7 m	• Ottawa River: SCUBA dive survey recorded live Hickorynut at depths between 1.5 and 6 m (Martel et al. 2006; COSEWIC 2011) • Mississagi River: total of ten live individuals were captured in water ranging from 1.5 to 4 m (Zanatta and Woolnough 2011) • St. Lawrence River (Grondines): Three live Hickorynut were recorded from at a depth of 0.5 m during low tide (A. Paquet, MRNF, unpubl. data) • Portneuf, Quebec (St. Lawrence River: Two live Hickorynut were	• Occupy a wide range of water depths, ranging from 0.5 to 9.7 m

Life Stage	Function	Feature(s)	Habitat Attributes: Scientific Literature	Habitat Attributes: Current Records	Habitat Attributes: For Identification of Critical Habitat
				recorded from a maximum sampling depth of 9.7 m (incidentally captured in two nets during fish surveys; 8.6 and 9.7 m) (P.-Y., Collin, MRNF, unpubl. data)	
			Water velocity • Descriptors such as occupying water of 'good current' (Metcalfe-Smith et al. 2005), 'moderate to strong current' (Parmalee and Bogan 1998, COSEWIC 2011) and 'moderate current' (Martel et al. 2006) have been used in the literature.	• Water velocity recorded during the 2012 sampling of live Hickorynut from Grondines, Quebec ranged from 0.0 to 0.3 m/s (A. Paquet, MRNF, unpubl. data).	
			Substrate • Substrate at sites where Hickorynut has been recorded is generally described as sandy (Parmalee and Bogan 1998), muddy sand or gravel (Watters et al. 2009), sand or mixed sand and gravel (Metcalfe-Smith et al. 2005) or sandy and silty sand bottom areas (D. Zanatta and A. Martel, pers. obs. in COSEWIC 2011)	• St. Lawrence River: composed of a mixture of sand, silt, and gravel (similar to scientific literature) • Batiscan River: sand-dominated (≥ 85% at all sites), • Saint-François River: very little sand (≤ 20% at all sites) and all sites were categorized as having relatively similar levels of bedrock, boulder and rubble, and trace amounts of gravel (differed significantly from description provided in scientific literature).	• Ability to survive in a wide range of substrate types, with the exception of muck and clay.
			Presence of dreissenid mussels • Introduction and establishment of dreissenid mussels has led to the decline of Hickorynut (COSEWIC 2011)	• Recent sampling (2004-12) has found the presence of Zebra Mussel attached to the shell of five live Hickorynut, and an additional four Hickorynut with byssal threads on their shells (A. Paquet, unpubl. data)	

Threats to Survival and Recovery

A wide variety of threats negatively impact Hickorynut across its range. Our knowledge of threat impacts on Hickorynut populations is limited to general documentation, as there is a paucity of threat-specific cause and effect information in the literature. The threats thought to have the largest effect on the survival and recovery of Hickorynut in Canada are largely attributed to the introduction and establishment of dreissenid mussels (Zebra Mussel, *Dreissena polymorpha*; Quagga Mussel, *Dreissena rostriformis*) and decreases in the quality of available freshwater mussel habitat. The introduction of dreissenid mussels is particularly relevant to remnant Hickorynut populations occupying the St. Lawrence River as Zebra Mussel are now present in the upper St. Lawrence River and appear to be affecting the presence of Hickorynut in this portion of the St. Lawrence River system. In addition, due to the obligate glochidial encystement stage, Hickorynut is directly affected by host fish abundance and indirectly affected by the threats affecting the host fish. Lesser threats that may be affecting the survival and recovery of Hickorynut include contaminants and toxic substances, nutrient loading, turbidity and sediment loading, and altered flow regimes. It is important to note the threats discussed may not always act independently on Hickorynut populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on Hickorynut populations. It is difficult to quantify these interactions; therefore, each threat is discussed independently.

Threat Level Assessment

Each threat was ranked in terms of the Threat Likelihood and Threat Impact for all river systems where it is believed that a population of Hickorynut may exist (see Bouvier et al. 2013 for complete details on classification approach). Threat Impact categorization was assigned on a location-by-location basis. If no information was available on the Threat Impact at a specific location, a precautionary approach was used - the highest level of impact from all sites was applied. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status Matrix resulting in the final Threat Status for each location (Table 3). Certainty has been classified for Threat Impact and is based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion [level of certainty listed from highest (1) to lowest (3)].

Table 3. Threat Level for Hickorynut populations, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Level, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion.

Threat	Mississagi River	Ottawa River	St. Lawrence River	Saint-François River
Invasive species	Medium (2)	High (2)	High (2)	Medium (2)
Host fish	High (2)	High (2)	High (2)	High (2)
Contaminants and toxic substances	Medium (3)	Medium (3)	Medium (3)	Medium (2)
Nutrient loading	Low (3)	Low (2)	Low (3)	Low (3)
Turbidity and sediment loading	Low (3)	Low (2)	Medium (3)	Medium (3)
Habitat removal and alteration	Medium (2)	High (2)	High (2)	High (2)
Altered flow regimes	Medium (1)	High (1)	Medium (1)	High (1)

Recovery Modelling

Host-Mussel Density Dependence

The Hickorynut Mussel's dependence on Lake Sturgeon was included in the model as follows: the probability of glochidial attachment (i.e., survival in the first year, σ_{gloch}) was assumed to be determined by the rate of host-mussel encounters. In particular, the probability of attachment was reduced as a function of the ratio between the abundance of age 1+ Lake Sturgeon (*H*) and adult mussel abundance (*M*).

Population Sensitivity

The assessment of population sensitivity involves perturbation analyses of population projection matrices, and includes a stochastic element. Outputs of the analyses include calculation of a population growth rate and its sensitivity to changes in vital rates (survival and fecundity). Sensitivity of this model was examined assuming i) host abundance exceeded the requirements of the mussel population (host independent model), or ii) host abundance affects glochidial survival (host dependent model). Model sensitivity to host abundance, host population trajectory, mussel life history, and host attachment probability were explored. See Young and Koops (2013) for complete details of the model and results.

In the host independent case, Hickorynut population growth rate is expected to be most sensitive to proportional changes in juvenile or adult survival, moderately sensitive to the age at maturity, and relatively insensitive to proportional changes in glochidial survival, fecundity, or maximum age (Figure 6).

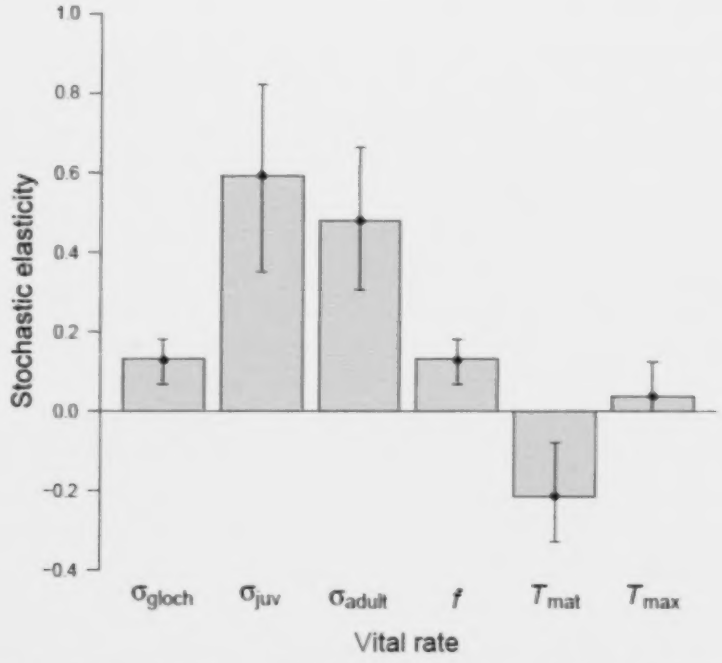

Figure 6. Results of the stochastic perturbation analysis showing elasticities (ε_v) of vital rates (annual survival probability for each stage, fecundity, age at maturity, and maximum age) for the host-independent model of Hickorynut. Results include associated bootstrapped 95% confidence interval. Exact values listed in Table 2 in Young and Koops (2013).

In the host-dependent case, given a declining host population, both host and mussel populations decreased until extinct regardless of mussel population trajectory (Figure 7a). Notice, however, that the adult mussel population may increase before it declines if the initial host abundance exceeds mussel requirements, or if there are large numbers of juveniles moving into the adult stage. In the latter case, the total mussel population is in decline even though adult numbers are temporarily increasing.

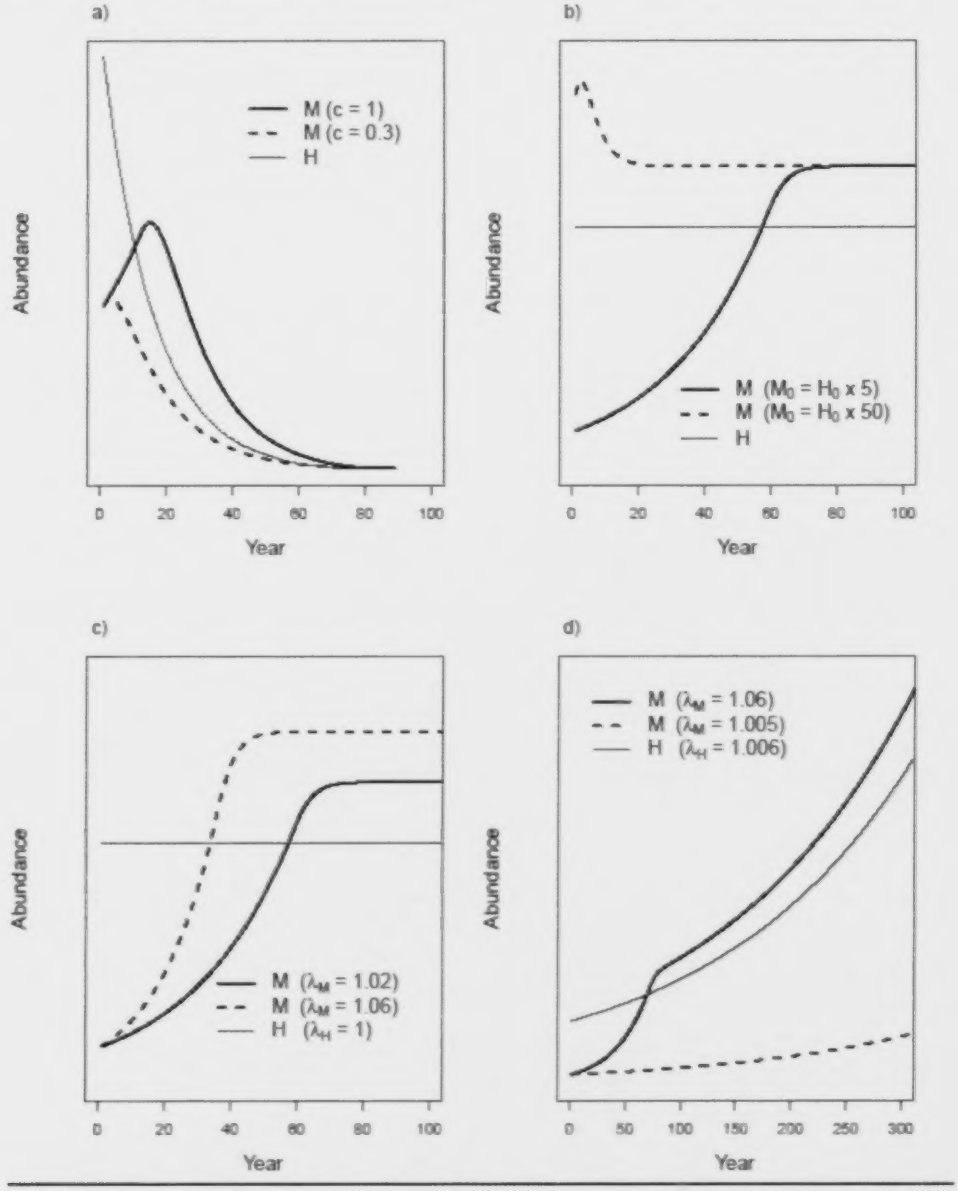

Figure 7. Abundance trajectories of Lake Sturgeon and host-dependent Hickorynut assuming a) a declining host population (λ=0.94), a growing mussel population (λ=1.02), and varying values of the constant c (equation (1)); b) a stable host population (λ=1), a growing mussel population (λ=1.02), and varying initial mussel populations; c) a stable host population, and mussel populations growing at varying rates; and d) a growing host population and mussel populations growing at varying rates.

Given a stable host population, a growing mussel population (i.e., a population that would continue to grow in the absence of host limitations) will stabilize to an equilibrium abundance (M^*) that is determined by the stable host abundance (H^*), the constant c (the mean annual probability of one host encountering each mussel), and the mussel's life history parameters (equation (1)).

$$M^* = \frac{f\sigma_{gloch}\sigma_{adult}\gamma_{juv}cH^*}{(\sigma_{juv}\gamma_{juv} - \sigma_{juv} + 1)(\sigma_{adult}\gamma_{adult} - \sigma_{adult} + 1)} \quad (1)$$

Assuming a stable host population, the expected equilibrium for a growing mussel population increases linearly with changes in fecundity, and exponentially with changes in adult or juvenile survival. The equilibrium abundance is independent of initial mussel population (Figure 7b), but dependent on the mussel's life history and natural growth rate (Figure 7c).

Given a growing host population, the mussel population growth rate cannot exceed that of the host population indefinitely (Figure 7d). That is, the mussel population will grow at the faster rate until it reaches its host-dependent growth capacity, which occurs when the host-dependent reduction in first year survival reduces the mussel population growth rate to the same rate as the host.

Mussel population abundance was very sensitive to the availability of juvenile hosts, and much less sensitive to the availability of adult hosts. In other words, a reduction in a host's capacity to accommodate glochidia due to smaller host size is much more detrimental than a reduction due to older age and/or acquired immunity. Note that these reductions in host availability assume that the hosts are merely unavailable to the glochidia, not removed from the population. Removal of hosts will affect the host population growth rate and its equilibrium abundance; decreases in host equilibrium abundance will affect mussel abundance linearly (equation (1)).

Allowable Harm

For the purposes of the recovery potential assessment modelling, the following definitions are used:

- Allowable harm is defined as harm to the population that will not jeopardize population recovery or survival.
- Chronic harm refers to a negative alteration to a vital rate that reduces a population growth rate over the long term.
- Transient harm refers to a one-time removal of individuals that reduces the mean population growth rate temporarily over a specific time-frame.

Estimates of allowable harm are very dependent on population trajectory and on species specific vital rates. Because there are so many unknown elements of Hickorynut life history, we do not provide specific allowable harm values here. Instead, we rely on model sensitivity to provide allowable harm advice; the more sensitive the model is to changes in a particular parameter, the more susceptible the population will be to harm affecting that life stage.

In general, if the host species is not limiting, Hickorynut population growth is most sensitive to perturbations that affect adult and juvenile survival. If host abundance is limiting, Hickorynut viability becomes sensitive to the rate of glochidial attachment.

Summary of Science Advice on Allowable Harm

Each element of allowable harm advice is independent and assumes no additional sources of harm. If there is harm from multiple sources, allowable harm should be reduced.

- Scientific research to advance the knowledge of population data should be allowed.

Allowable Chronic Harm

- When Hickorynut population trajectory is declining or stable there is no scope for allowable chronic harm (i.e., at the population level).
- When Hickorynut population trajectory is growing then chronic harm may be considered if Lake Sturgeon population trajectory is stable or growing. Any chronic harm, especially to annual survival rates of Hickorynut, may delay recovery.
- When population trajectory is unknown the scope for allowable chronic harm can only be assessed once population data are collected.

Allowable Transient Harm

- When Hickorynut population trajectory is declining or unknown, even low levels of transient harm may compromise recovery or shorten the time to extirpation.
- When Hickorynut population trajectory is growing or stable, transient harm may be considered if Lake Sturgeon population trajectory is stable or growing. Magnitude of harm should be based on the nearness of Hickorynut abundance to its equilibrium abundance as defined in the host-dependent modelling.
- Harm (either chronic or transient) that restricts host availability for attachment of Hickorynut glochidia should be avoided or mitigated.

Mitigations and Alternatives

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects, or activities in Hickorynut habitat. Hickorynut has been assessed as Endangered by COSEWIC and is currently listed as Endangered and protected under Ontario's *Endangered Species Act 2007*, which necessitates the preparation of a formal provincial recovery strategy for Hickorynut to manage the species and prevent further decline.

The Hickorynut is also a candidate species for listing under the *Species at Risk Act* and a recovery potential assessment (RPA) must be performed to inform the listing decision. The RPA process includes the information on works and undertakings in Hickorynut habitat and on mitigation measures. As the Hickorynut is present in Ontario and Quebec, the results will be presented by province in the text, but by Hickorynut population in the tables. Note that pathways of effects are the same for both provinces but Quebec does not have a referrals streamlining process as extensive as the Ontario one which is used to provide relevant information on threats and mitigations in the RPA.

Within Hickorynut habitat, a variety of works, undertakings, and activities have occurred in the past few years including: water crossings (e.g., bridges and culverts); shoreline and streambank works (e.g., stabilization); in-stream works (e.g., channel maintenance, modifications or realignments); the placement of structures in water (e.g., boat launches, docks, effluent outfalls, water intakes); and, water management activities (e.g., stormwater management). Research has been completed summarizing the types of work, activity, or project that have been undertaken in habitat known to be occupied by Hickorynut (Table 4). The DFO Program Activity Tracking for Habitat (PATH) database, as well as summary reports of fish habitat projects reviewed by partner agencies (e.g., conservation authorities), have been reviewed to estimate the number of projects that have occurred during the three-year period, 2009-2011. Approximately 133 projects were identified in Ontario and 55 in Quebec but likely do not represent a comprehensive list of activities that have occurred in these areas (Table 4). Some

projects may not have been reported to partner agencies or DFO if they occurred under conditions of an Operational Statement. However, 9 were completed under conditions of Operational Statements primarily for structures in water (such as docks and boat launches) and shoreline or streambank works (such as stabilization).

The remaining projects were deemed low risk to fish and fish habitat and were addressed through letters of advice with standard mitigation. Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have affected Hickorynut (e.g., increased turbidity or sedimentation from upstream channel works). The majority of projects (42 percent) were for shoreline stabilization works. Based on the assumption that historic and anticipated development pressures are likely to be similar, it is expected that similar types of projects will likely occur in or near Hickorynut habitat in the future. The primary project proponents were individual landowners in Ontario and municipalities in Quebec.

As indicated in the Threat Analysis, numerous threats affecting Hickorynut populations are habitat-related threats that have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 4). DFO FHM has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. At the present time, we are unaware of mitigation that would apply beyond what is included in the Pathways of Effects.

Additional mitigation and alternative measures, specific to Hickorynut, related to invasive species, and host fish.

Table 4. Summary of works, projects and activities that have occurred during the period of January 2009 to December 2011 in areas known to be occupied by Hickorynut. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Hickorynut population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects have been indicated for each threat associated with a work, project or activity (1 - Vegetation clearing; 2 – Grading; 3 –Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)							**Watercourse / Waterbody** (number of works/projects/activities between 2009-2011)			
	Invasive species	**Host Fish (Barriers to movement)**	**Contaminants & toxic substances**	**Nutrient loading**	**Turbidity and sediment loading**	**Habitat removal and alteration**	**Altered flow regimes**	**Mississagi River**	**Ottawa River**	**St. Lawrence River**	**St. François River**
Applicable pathways of effects for threat mitigation and project alternatives		10, 16, 17	1, 4, 5, 6, 7, 11, 12, 13, 14, 15, 16, 18	1, 4, 7, 8, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 18	10, 11, 12, 16, 18				
Water crossings (bridges, culverts, open cut crossings)		✓	✓		✓	✓		6	9	2	1
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)			✓		✓	✓			63	15	1
Dams, barriers, structures in water (maintenance, modification, hydro retrofits)	✓	✓			✓	✓	✓	1	1	1	

Work/Project/Activity	Threats (associated with work/project/activity)							Watercourse / Waterbody (number of works/projects/activities between 2009-2011)			
	Invasive species	Host Fish (Barriers to movement)	Contaminants & toxic substances	Nutrient loading	Turbidity and sediment loading	Habitat removal and alteration	Altered flow regimes	Mississagi River	Ottawa River	St. Lawrence River	St. François River
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)			✓	✓	✓	✓			8	12	
Water management (stormwater management, water withdrawal)			✓	✓	✓		✓		6		
Structures in water (boat launches, docks, effluent outfalls, water intakes)			✓	✓	✓	✓		2	43	16	1
Baitfishing											
Invasive species introductions (accidental and intentional)	✓										

Invasive Species

Aquatic invasive species (e.g., dreissenid mussels) introduction and establishment have had negative effects on Hickorynut populations. Mitigation and alternatives should not only be considered for current established invasive species but species that may invade in the future.

Mitigation

- Evaluate the likelihood that a waterbody will be invaded by an invasive species.
- Monitor watersheds for invasive species that may negatively affect Hickorynut populations directly, or negatively affect Hickorynut habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an invasive species.
- Introduce a public awareness campaign on proper boat cleaning methods when transferring boats from an infested waterway, and on the proper identification of native and invasive freshwater mussels. The public awareness campaign could include an educational fact sheet to better educate the public on native and invasive species.
- Encourage the use of existing invasive species reporting systems
- Restrict the use of boats in areas particularly susceptible to Zebra Mussel introduction and infestation.

Alternatives

- Unauthorized
  - None.
- Authorized
  - Use only native species.
  - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Host Fish

Decreases in the number of individual host fish or decreases in the area of overlap between host fish and freshwater mussel may be decreasing the likelihood that a fish-mussel encounter will occur.

Mitigation

- Implement a management plan for the appropriate host fish species. This would increase the host's survival, increasing number of host individuals, creating a healthy host population and subsequently increasing the likelihood that the host fish would encounter a gravid freshwater mussel.
- Immediate release of host fish if caught angling in areas where freshwater mussels of concern are known to occur.

Alternatives

- Seasonal or zonal restrictions applied to Lake Sturgeon harvest if period of Hickorynut glochidial attachment can be confirmed for natural infestations.

Sources of Uncertainty

Despite concerted efforts to increase our knowledge of Hickorynut in Canada, there are still a number of key sources of uncertainty for this species related to population distribution, structure, habitat preferences and to the factors limiting their existence.

There is a need for a continuation of quantitative sampling of Hickorynut in areas where it is known to occur to determine population size, current trajectory, and trends over time. There is also a need for additional targeted sampling in Mississagi, Ottawa and Saint-François rivers to confirm the current population status assessment, and to determine population sizes. Exploratory sampling should be completed in systems with habitat characteristics similar to those areas where Hickorynut is known to occur to determine the extent of their distribution. Candidate systems for exploratory surveys would include the Mattawa, French and Gatineau rivers, and Lake Nipissing which are in close proximity to locations where Hickorynut have been recorded and may contain suitable habitat. Additional sampling is necessary for all populations that were assigned a low certainty in completing the population status assessment. Many of the historic Hickorynut sites in the Ottawa River have yet to be recently surveyed. Areas of particular interest in the Ottawa River include areas north of the Timiskaming records, including the Blanche River, the Ottawa River between the Timiskaming region and the Ile-aux-Allumettes, and the length of river between MacLaren's Landing and the confluence of the Ottawa River with the St. Lawrence River. Sampling efforts in the Saint-François River should be continued and expanded both upstream of the Domtar generating station, and downstream of the Drummondville generating station. Tributaries of the North Channel (Lake Huron) and potentially Lake Superior with habitat characteristics similar to those of the Mississagi River, and inhabited by Lake Sturgeon, should be sampled to determine if the Hickorynut population in the Mississagi represents a disjunct population. As Hickorynut is often found in deeper water, SCUBA surveys are required for all populations. Additional experimental sampling methods should be investigated to sample deep water habitats, including the use of brails. Brails are boards with a fringe of short chains to which hooks are attached, and each hook generally has four prongs with a bead at the end of each prong. When the brail is lowered in the river and pulled along the river bottom, the mussel clamps down on the beaded end and is pulled out of the substrate. During surveys, the shell length of all live individuals should be recorded to gain information on population structure and to understand recruitment within each population. These baseline data are required to monitor Hickorynut distribution and population trends as well as the success of any recovery measures implemented. If live Hickorynut can be successfully captured, there is a need to determine abundance estimates to properly interpret population modelling (see Young and Koops 2013). Certain life history characteristics also required to inform Hickorynut population modeling efforts are currently unknown. Studies to validate stage specific survival, fecundity, age at maturity, longevity, and population abundance are required. Further studies should focus on acquiring details about host infestation on all sizes of host (such as numbers of glochidia), as well as the relationship between mussel attachment probability and host-mussel density.

Additional studies on habitat requirements are imperative to determine critical habitat for all Hickorynut life stages. Additional studies on the preferred habitat of this species may also help to determine possible candidate areas for relocation. Additional sampling should include a quantitative habitat assessment including substrate categorization, water depth, and water velocity. There is a need to better understand the effects of water level variation and changes to natural flow regimes on Hickorynut. Supplementary laboratory experiments, and if feasible field experiments, should be completed to determine if Lake Sturgeon is indeed the host fish for Hickorynut in Canada. Laboratory infestation experiments, using samples from Canadian populations, should be completed to verify the usage of Lake Sturgeon as the host fish for

Hickorynut. Lake Sturgeon sampling should be completed, during which the gills should be inspected and sampled for Hickorynut glochidia. If Lake Sturgeon is confirmed as the host fish for Canadian populations of Hickorynut, Lake Sturgeon movement and migratory patterns should be investigated to determine Hickorynut dispersal within and between populations. Also, once Lake Sturgeon is confirmed to be the host fish for Hickorynut, additional modelling efforts should be completed to estimate the number of Lake Sturgeon required to support the Hickorynut population. Other potential host fish, such as Freshwater Drum (*Aplodinotus grunniens*), should be included in infestation experiments to determine if additional species may act as suitable host fish for Hickorynut. Numerous threats have been identified for Hickorynut populations in Canada, although the direct impact that these threats might have is currently unknown. There is a need for more quantitative studies to evaluate the direct impact of each threat on Hickorynut populations with greater certainty. In the literature, the threat impacts are generally discussed at a broad level (i.e., mussel assemblage level). It is important to further our knowledge on threat likelihood and impact at the species level. Research is needed to determine the direct and indirect effects that dreissenid mussels may have on Hickorynut. This type of species-specific threat research of invasive species on native mussels is needed to better inform decisions on the management of invasive species. There is a need to determine threshold levels for water quality parameters (e.g., nutrients, turbidity).

SOURCES OF INFORMATION

This Science Advisory Report is from the January 29-30, 2013 Recovery Potential Assessment of Hickorynut (*Obovaria olivaria*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Bouvier, L.D., Paquet, A., and Morris, T.J. 2013. Information in support of a recovery potential assessment of Hickorynut (*Obovaria olivaria*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/041. v + 42 p.

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